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(54) **CAMERA OPTICAL LENS**

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G02B 13/00 (2006.01)

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CPC **G02B 13/004** (2013.01); **G02B 9/34** (2013.01)

(58) **Field of Classification Search**
CPC G02B 13/004; G02B 9/34
See application file for complete search history.

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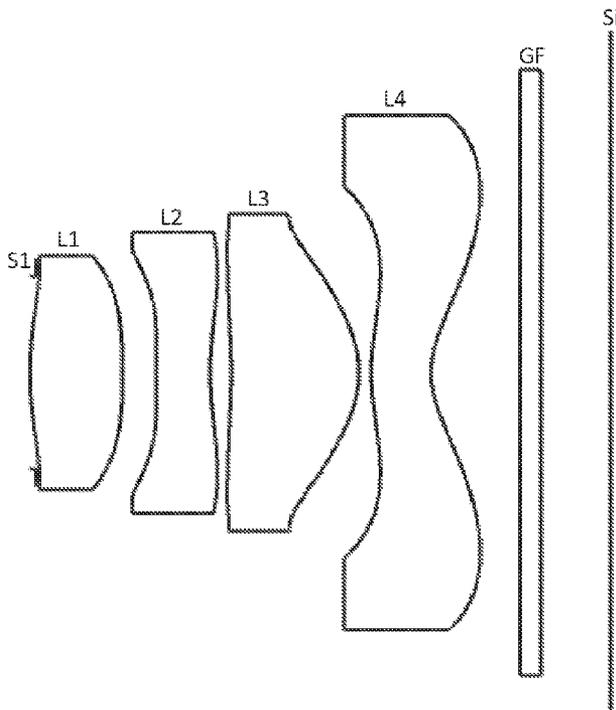
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(57) **ABSTRACT**

Disclosed is a camera optical lens comprising, from an object side to an image side in sequence: a first lens having a positive refractive power; a second lens having a negative refractive power; a third lens having a positive refractive power; and a fourth lens having a negative refractive power; the camera optical lens satisfies: $-0.40 \leq (R1+R2)/(R1-R2) \leq -0.20$; $1.50 \leq (R3+R4)/(R3-R4) \leq 2.00$; $1.20 \leq (R5+R6)/(R5-R6) \leq 1.80$; and $1.52 \leq d3/d2 \leq 1.80$; where, R1 and R2 denote central curvature radii of object and image side surfaces of the first lens respectively; R3 and R4 denote central curvature radii of object and image side surfaces of the second lens respectively; R5 and R6 denote central curvature radii of object side surface and image side surface of the third lens respectively; d2 denotes an on-axis distance from image side surface of first lens to object side surface of second lens L2; and d3 denotes an on-axis thickness of the second lens.
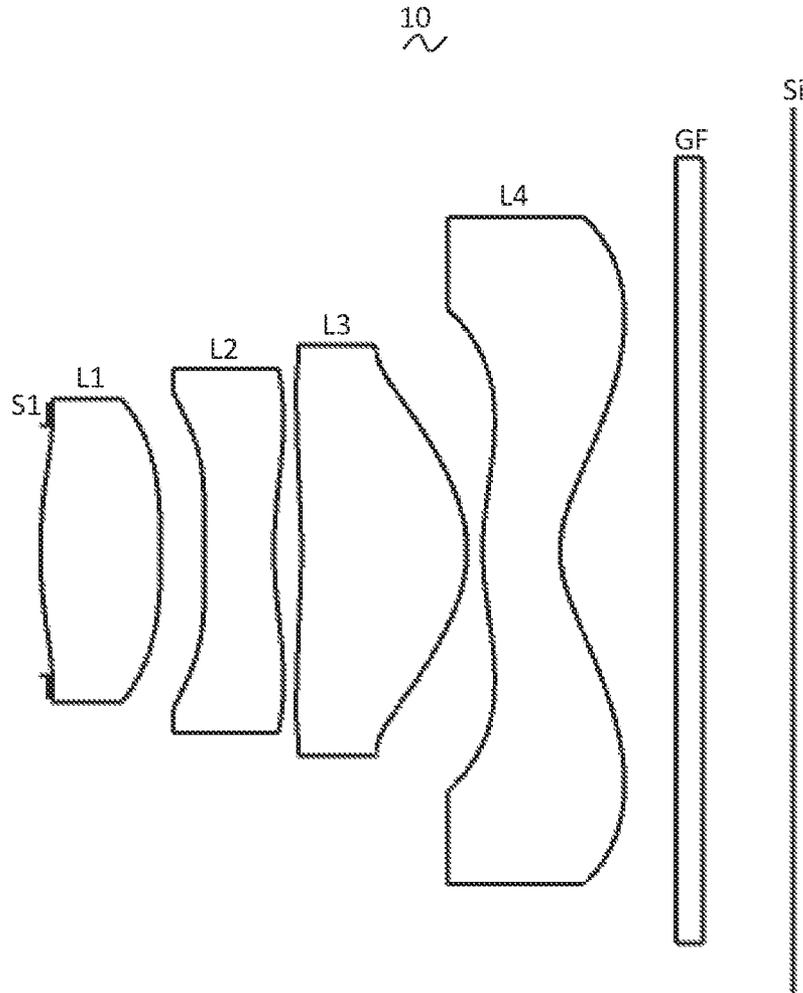
10 Claims, 7 Drawing Sheets

FIG. 1
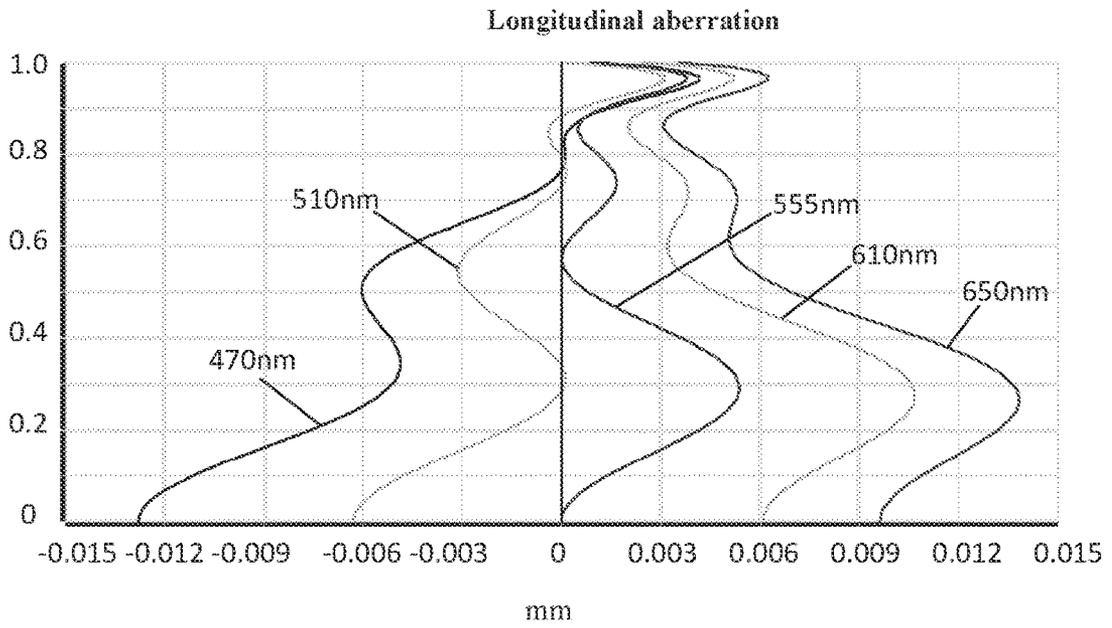
Longitudinal aberration

FIG. 2

Lateral color

FIG. 3

FIG. 4

FIG. 5

FIG. 6

Lateral color

FIG. 7

Field curvature

Distortion

FIG. 8

30

FIG. 9

Longitudinal aberration

555nm

610nm

650nm

470nm

510nm

mm

FIG. 10

Lateral color

FIG. 11

Field curvature

Distortion
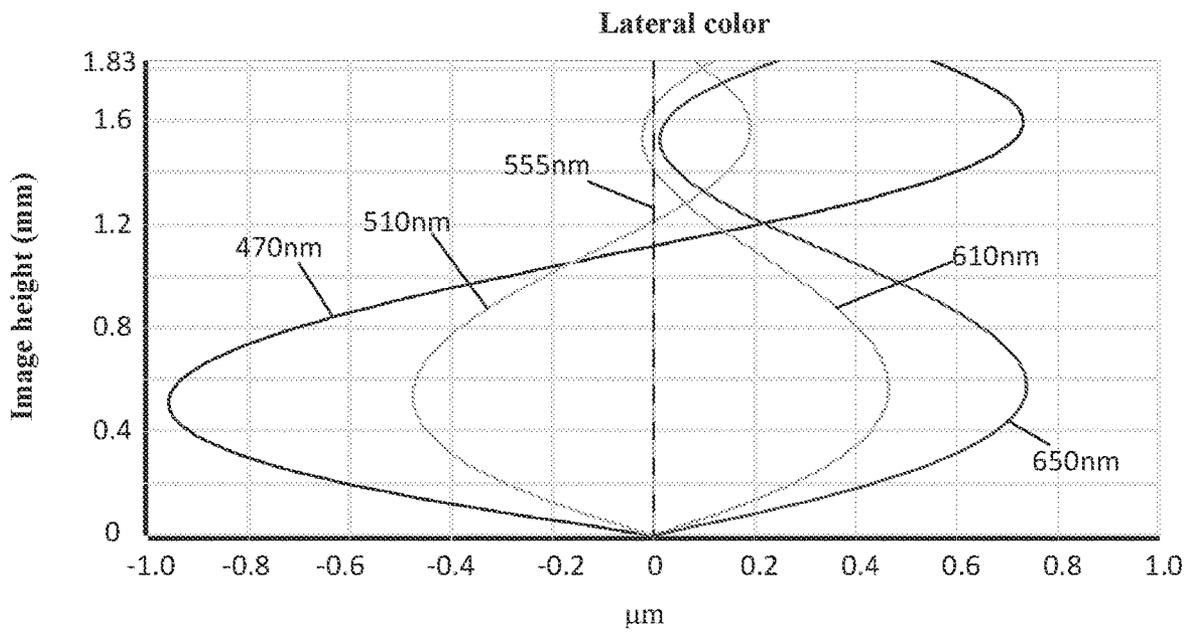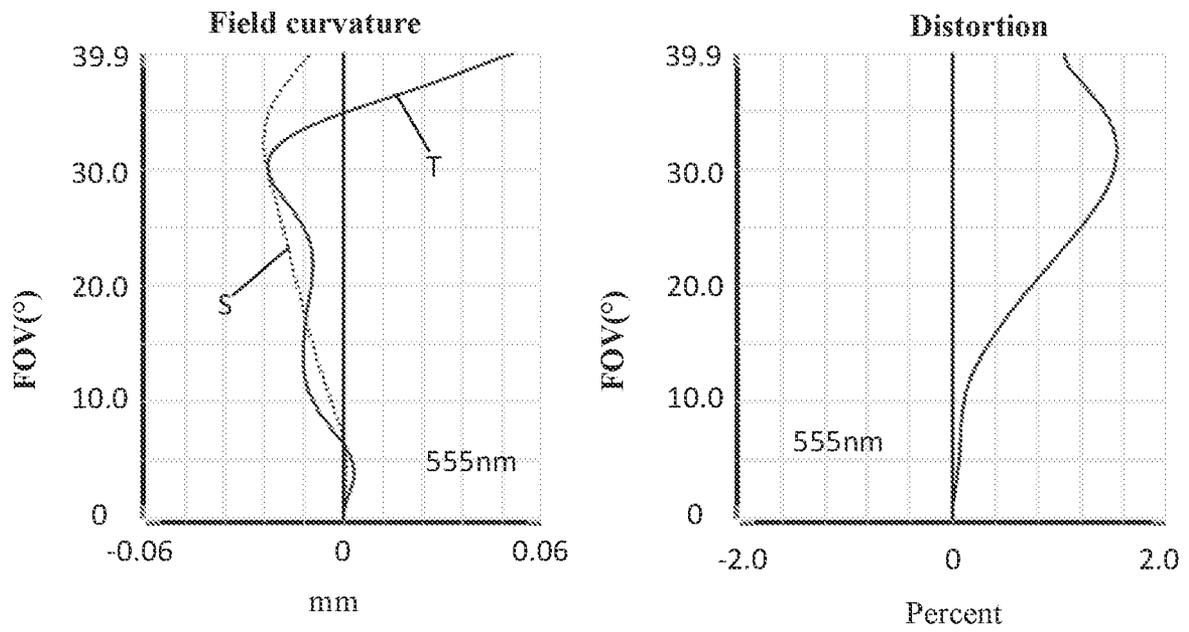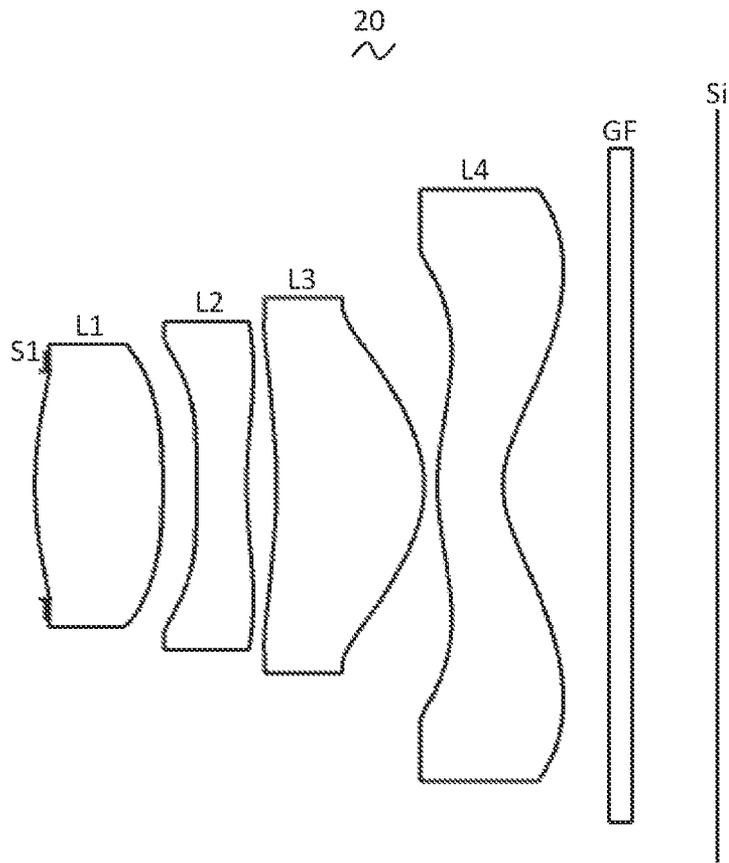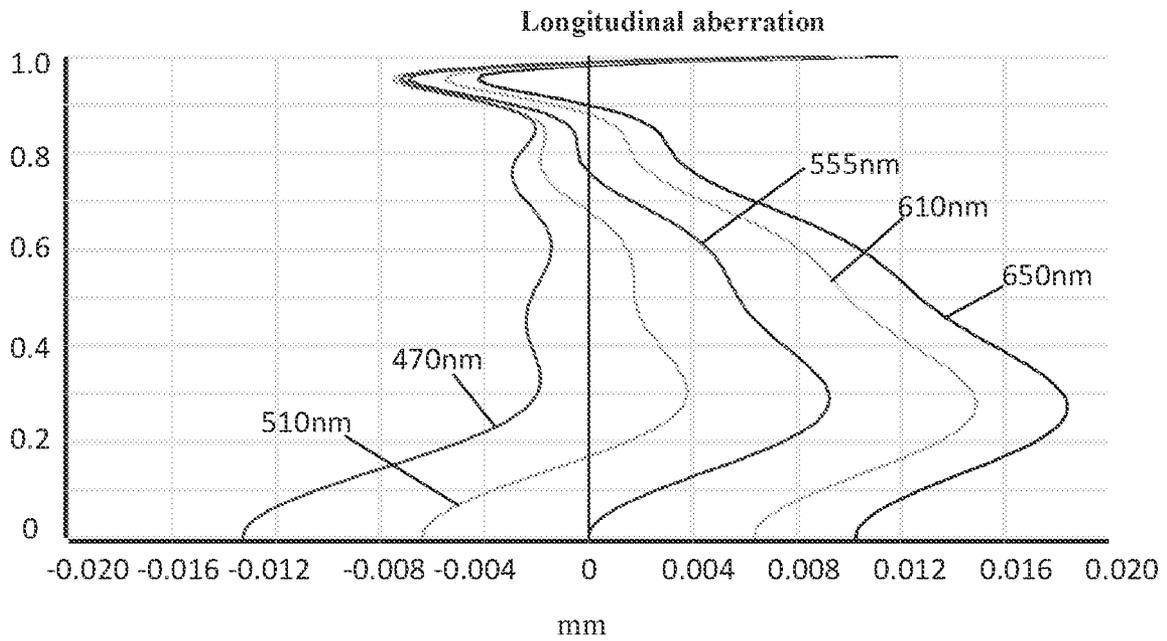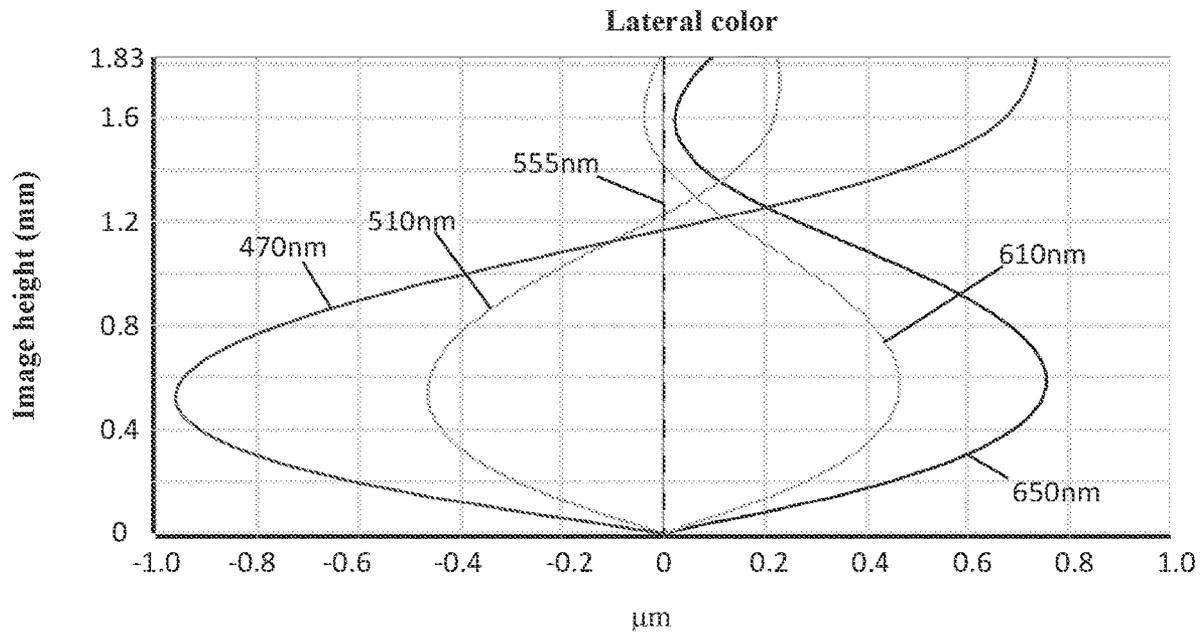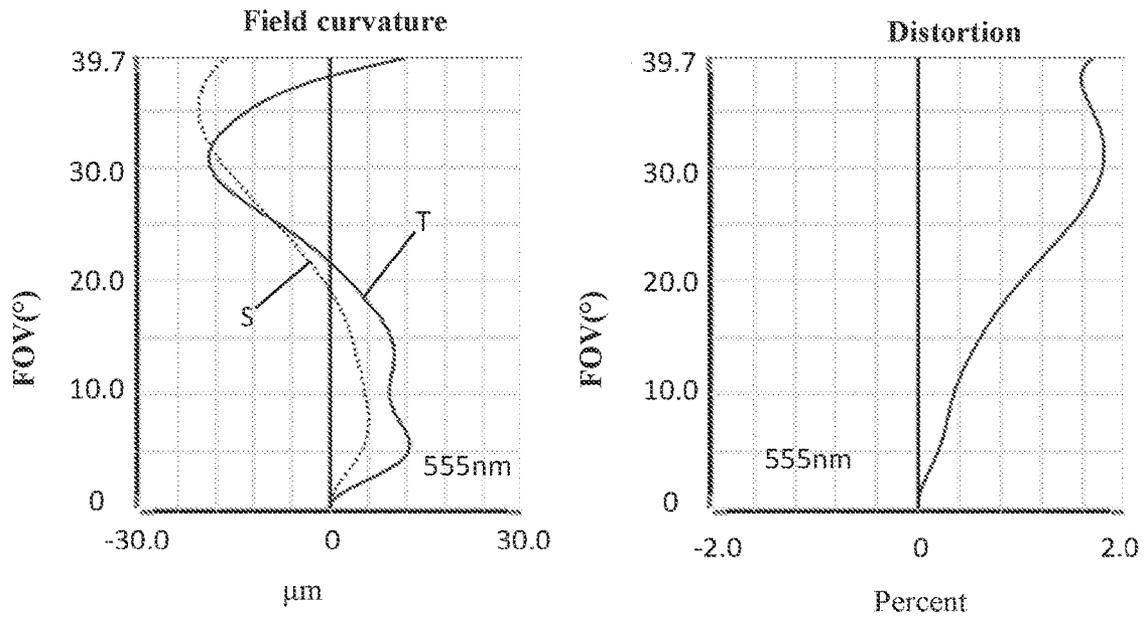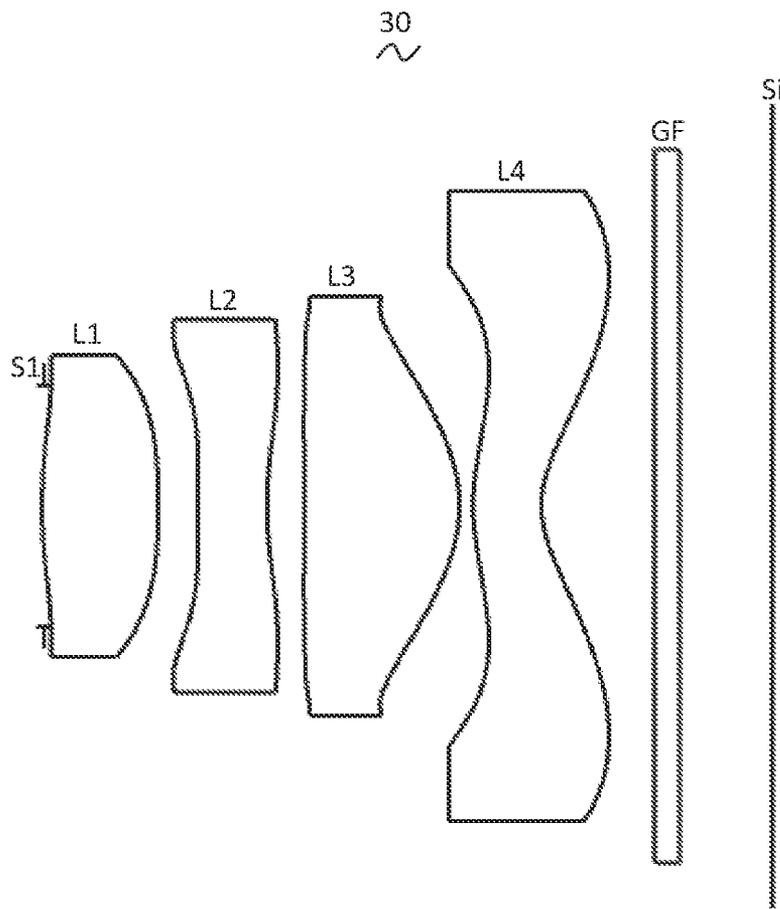
FIG. 12

CAMERA OPTICAL LENS

TECHNICAL FIELD

The present disclosure generally relates to optical lens, in particular to a camera optical lens suitable for handheld terminals, such as smart phones and digital cameras, and imaging devices, such as monitors and PC lens.

BACKGROUND

With the emergence of smart phones in recent years, the demand for miniature camera lens is increasing day by day, but in general the photosensitive devices of camera lens are nothing more than Charge Coupled Device (CCD) or Complementary Metal-Oxide Semiconductor Sensor (CMOS sensor). As the progress of the semiconductor manufacturing technology makes the pixel size of the photosensitive devices become smaller, and with the current development trend of electronic products towards better functions and thinner and smaller dimensions, miniature camera lens with good imaging quality therefore have become a mainstream in the market.

In order to obtain better imaging quality, the lens that is traditionally equipped in mobile phone cameras adopts a three-piece or four-piece lens structure. The common four-piece lens has good optical performance, but the design on focal power, lens spacing and lens shape is not reasonable, thus the lens structure could not meet the requirements for having a large aperture, a wide angle and ultra-thinness while having good optical performance.

SUMMARY

Some embodiments of the present disclosure provide a camera optical lens, comprising five lenses in total, camera optical lens, comprising four lenses, the four lenses are, from an object side to an image side in sequence: a first lens having a positive refractive power; a second lens having a negative refractive power; a third lens having a positive refractive power; and a fourth lens having a negative refractive power; wherein, the camera optical lens satisfies the following conditions: $-0.40 \leq \leq (R1+R2)/(R1-R2) \leq -0.20$; $1.50 \leq (R3+R4)/(R3-R4) \leq 2.00$; $1.20 \leq (R5+R6)/(R5-R6) \leq 1.80$; and $1.52 \leq d3/d2 \leq 1.80$; where, R1 denotes a central curvature radius of an object side surface of the first lens; R2 denotes a central curvature radius of an image side surface of the first lens; R3 denotes a central curvature radius of an object side surface of the second lens; R4 denotes a central curvature radius of an image side surface of the second lens; R5 denotes a central curvature radius of an object side surface of the third lens; R6 denotes a central curvature radius of an image side surface of the third lens; and d2 denotes an on-axis distance from the image side surface of the first lens to the object side surface of the second lens L2; and d3 denotes an on-axis thickness of the second lens.
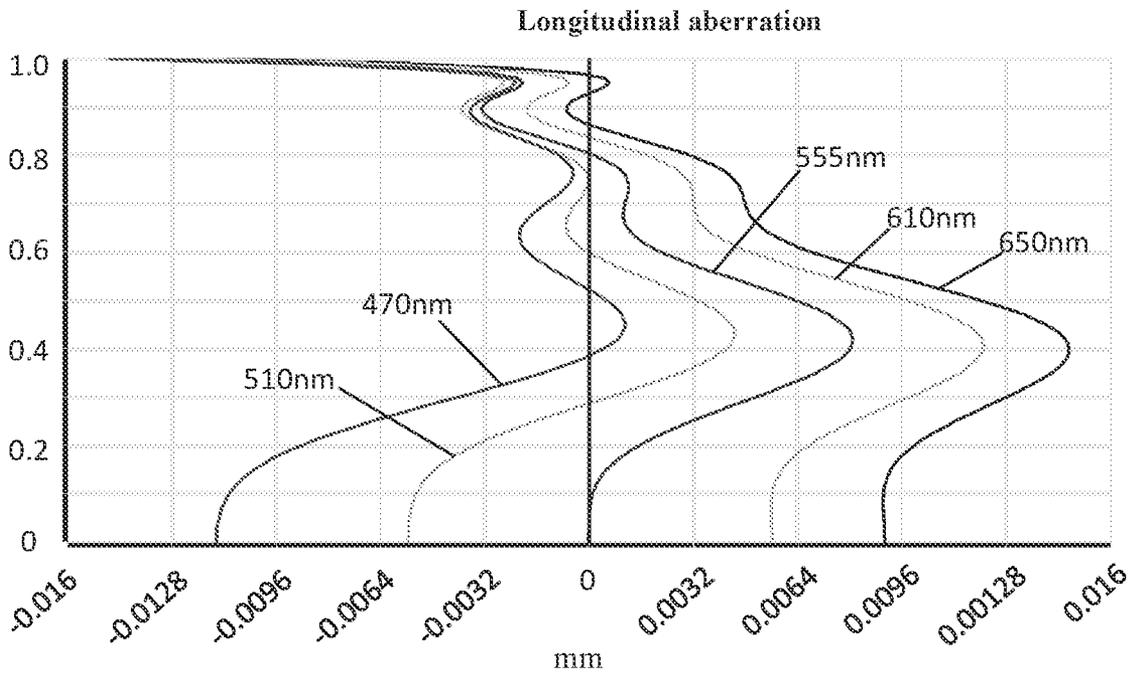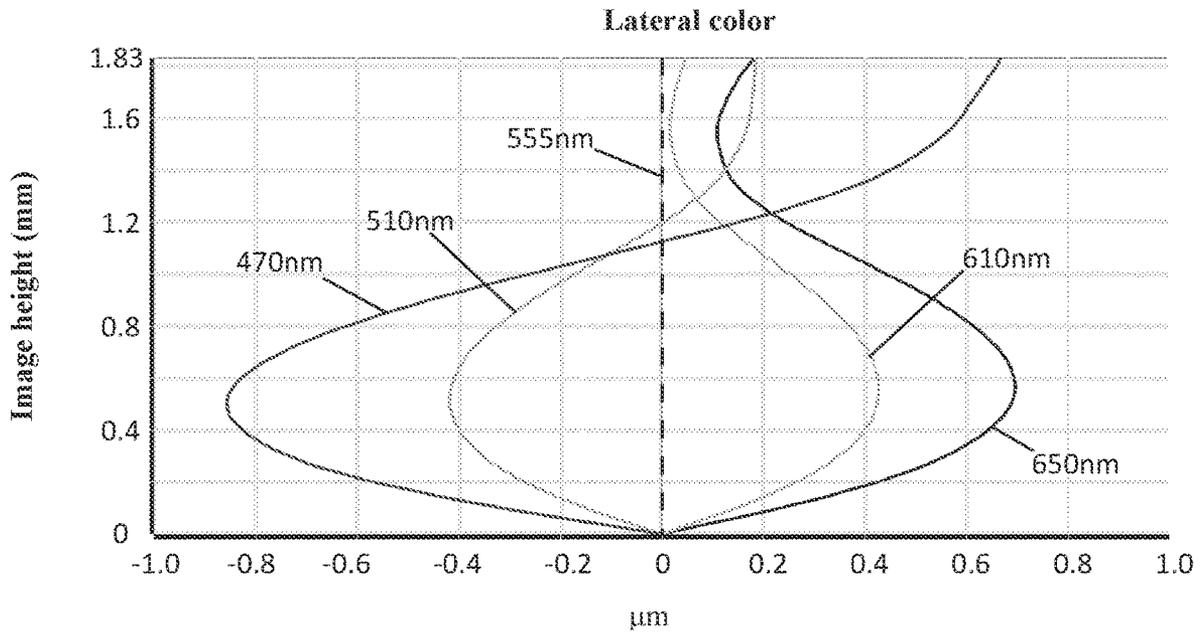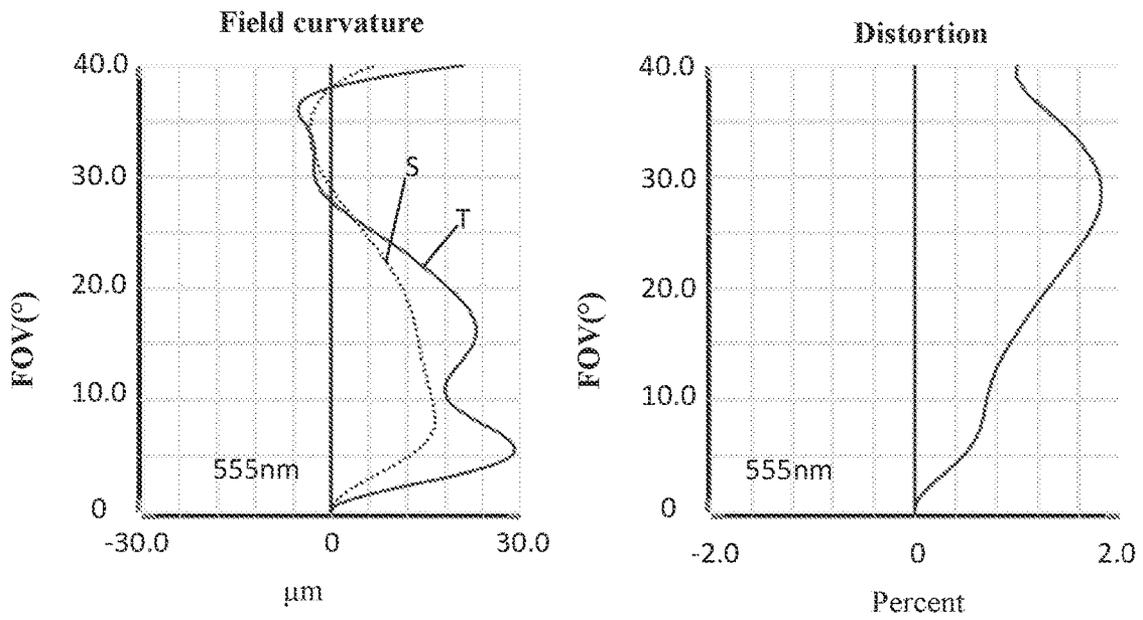
As an improvement, the camera optical lens further satisfies the following conditions: $-0.70 \leq f1/f2 \leq -0.50$; wherein, f1 denotes a focus length of the first lens; and f2 denotes a focus length of the second lens.

As an improvement, the camera optical lens satisfies the following conditions: $0.55 \leq f1/f \leq 1.89$; and $0.08 \leq d1/TTL \leq 0.28$; wherein, f denotes a focus length of the camera optical lens; f1 denotes a focus length of the first lens; d1 denotes an on-axis thickness of the first lens; and TTL denotes a total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis.

As an improvement, the camera optical lens further satisfies the following conditions: $-4.19 \leq f2/f \leq -1.24$; and $0.04 \leq d3/TTL \leq 0.14$; wherein, f denotes a focus length of the camera optical lens; f2 denotes a focus length of the second lens; and TTL denotes a total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis.

As an improvement, the camera optical lens satisfies the following conditions: $0.31 \leq f3/f \leq 0.93$; and $0.11 \leq d5/TTL \leq 0.33$; wherein, f denotes a focus length of the camera optical lens; f3 denotes a focus length of the third lens; d5 denotes an on-axis thickness of the third lens; and TTL denotes a total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis.

As an improvement, the camera optical lens satisfies the following conditions: $-1.64 \leq f4/f \leq -0.52$; $1.12 \leq (R7+R8)/(R7-R8) \leq 3.81$; and $0.05 \leq d7/TTL \leq 0.15$; wherein, f denotes a focus length of the camera optical lens; f4 denotes a focus length of the fourth lens; R7 denotes a central curvature radius of an object side surface of the fourth lens; R8 denotes a central curvature radius of an image side surface of the fourth lens; d7 denotes an on-axis thickness of the fourth lens; and TTL denotes a total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis.

As an improvement, the camera optical lens further satisfies the following conditions: $FNO \leq 1.95$; where, FNO denotes an aperture value of the camera optical lens.

As an improvement, the camera optical lens further satisfies the following conditions: $FOV \geq 79°$; wherein, FOV denotes a field of view of the camera optical lens.

As an improvement, the camera optical lens further satisfies the following conditions: $TTL/IH \leq 1.76$; wherein, TTL denotes a total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis; and IH denotes an image height of the camera optical lens.

As an improvement, the camera optical lens satisfies the following conditions: $0.91 \leq f12/f \leq 3.90$; wherein, f denotes a focus length of the camera optical lens; and f12 denotes a combined focal length of the first lens and the second lens.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to explain the technical solutions in the embodiments of the present disclosure more clearly, the drawings to be used for describing the embodiments will be described briefly in the following. Apparently, the drawings in the following are only for facilitating the description of the embodiments, for those skilled in the art, other drawings may be obtained from the accompanying drawings without creative work.

FIG. 1 is a schematic diagram of a structure of a camera optical lens in accordance with Embodiment 1 of the present disclosure;

FIG. 2 is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. 1;

FIG. 3 is a schematic diagram of a lateral color of the camera optical lens shown in FIG. 1;

FIG. 4 is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. 1;

FIG. **5** is a schematic diagram of a structure of a camera optical lens in accordance with Embodiment 2 of the present disclosure;

FIG. **6** is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. **5**;

FIG. **7** is a schematic diagram of a lateral color of the camera optical lens shown in FIG. **5**;

FIG. **8** is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. **5**;

FIG. **9** is a schematic diagram of a structure of a camera optical lens in accordance with Embodiment 3 of the present disclosure;

FIG. **10** is a schematic diagram of a longitudinal aberration of the camera optical lens shown in FIG. **9**;

FIG. **11** is a schematic diagram of a lateral color of the camera optical lens shown in FIG. **9**;

FIG. **12** is a schematic diagram of a field curvature and a distortion of the camera optical lens shown in FIG. **9**.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

To make the objects, technical solutions, and advantages of the present disclosure clearer, the embodiments of the present disclosure are described in detail with reference to the accompanying drawings as follows. A person of ordinary skill in the related art would understand that, in the embodiments of the present disclosure, many technical details are provided to make readers better understand this application. However, the technical solutions sought to be protected by this application could be implemented, even without these technical details and any changes and modifications based on the following embodiments.

Embodiment 1

As shown in the accompanying drawings, the present disclosure provides a camera optical lens **10**. FIG. **1** shows the camera optical lens **10** of Embodiment 1 of the present disclosure, the camera optical lens **10** comprises four lenses in total. Specifically, the camera optical lens **10** comprises in sequence from an object side to an image side: an aperture S1, a first lens L1, a second lens L2, a third lens L3 and a fourth lens L4. An optical element such as an optical filter GF may be arranged between the fourth lens L4 and an image surface Si.

In this embodiment, the first lens L1 has a positive refractive power, the second lens L2 has a negative refractive power, the third lens L3 has a positive refractive power, and the fourth lens L4 has a negative refractive power.

In this embodiment, the first lens L1, the second lens L2, the third lens L3 and the fourth lens L4 are all made of plastic material. In some embodiments, the lenses may also be made of other materials.

A central curvature radius of an object side surface of the first lens L1 is defined as R1, and a central curvature radius of an image side surface of the first lens L1 is defined as R2. The camera optical lens **10** satisfies a condition of $-0.40 \leq (R1+R2)/(R1-R2) \leq -0.20$, which specifies a shape of the first lens. When the above condition is satisfied, it is beneficial for correction of spherical aberration and improving imaging quality.

A central curvature radius of an object side surface of the second lens L2 is defined as R3, and a central curvature radius of an image side surface of the second lens L2 is defined as R4. The camera optical lens **10** further satisfies a condition of $1.50 \leq (R3+R4)/(R3-R4) \leq 2.00$, which specifies

a shape of the second lens. When the above condition is satisfied, it is beneficial for lens processing.

A central curvature radius of an object side surface of the third lens L3 is defined as R5, and a central curvature radius of an image side surface of the third lens L3 is defined as R6. The camera optical lens **10** satisfies a condition of $1.20 \leq (R5+R6)/(R5-R6) \leq 1.80$, which specifies a shape of the third lens L3. When the above condition is satisfied, the degree of light deflection when passing through the lens may be reduced, and thus the aberration is effectively reduced.

An on-axis distance from the image side surface of the first lens L1 to the object side surface of the second lens L2 is defined as d2, and an on-axis thickness of the second lens L2 is defined as d3. The camera optical lens **10** further satisfies a condition of $1.52 \leq d3/d2 \leq 1.80$. When d3/d2 satisfies the above condition, the ratio of the on-axis thickness d3 of the second lens L2 and the on-axis distance d2 from the image side surface of the first lens L1 to the object side surface of the second lens L2 can be effectively distributed, and thus the system sensitivity is lowered and the production yield is improved.

A focal length of the first lens L1 is defined as f1; and a focal length of the second lens is defined as f2. The camera optical lens **10** satisfies a condition of $-0.70 \leq f1/f2 \leq -0.50$, which specifies a ratio between the focal length f1 of the first lens L1 and focal length f2 of the second lens. When the above condition is satisfied, it is beneficial for balancing abbreviation and improving imaging quality.

In this embodiment, the object side surface of the first lens L1 is convex in a paraxial region, and the image side surface of the first lens L1 is convex in the paraxial region.

A focal length of the camera optical lens **10** is defined as f, and a focal length of the first lens L1 is defined as f1. The camera optical lens **10** satisfies a condition of $0.55 \leq f1/f \leq 1.89$, which specifies a ratio between the focal length f1 of the first lens L1 and the focal length f of the camera optical lens **10**. When the above condition is satisfied, the first lens has an appropriate positive refractive power, which is beneficial for reducing system abbreviation as well as developing towards a lens with ultra-thinness and a wide angle. Preferably, the camera optical lens **10** further satisfies a condition of $0.89 \leq f1/f \leq 1.51$.

An on-axis thickness of the first lens L1 is defined as d1, and a total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis is defined as TTL. The camera optical lens **10** satisfies a condition of $0.08 \leq d1/TTL \leq 0.28$. When the above condition is satisfied, it is beneficial for realization of ultra-thin lenses. Preferably, the camera optical lens **10** further satisfies a condition of $0.13 \leq d1/TTL \leq 0.22$.

In this embodiment, the object side surface of the second lens L2 is convex in a paraxial region, and the image side surface of the second lens L2 is concave in the paraxial region.

The focal length of the camera optical lens **10** is defined as f, and a focal length of the second lens L2 is defined as f2. The camera optical lens **10** satisfies a condition of $-4.19 \leq f2/f \leq -1.24$. It is beneficial for correcting aberration of an optical system by controlling a negative focal power of the second lens L2 within a reasonable range. Preferably, the camera optical lens **10** further satisfies a condition of $-2.62 \leq f2/f \leq -1.55$.

An on-axis thickness of the second lens L2 is defined as d3, and the total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis is defined as TTL. The camera optical lens **10** satisfies a condition of $0.04 \leq d3/TTL \leq 0.14$. When the

above condition is satisfied, it is beneficial for realization of ultra-thin lenses. Preferably, the camera optical lens 10 further satisfies a condition of 0.06≤d3/TTL≤0.11.

In this embodiment, an object side surface of the third lens L3 is concave in a paraxial region, and an image side surface of the third lens L3 is convex in the paraxial region.

A focal length of the third lens L3 is defined as f3 and a focal length of the camera optical lens 10 is defined as f. The camera optical lens 10 satisfies a condition of 0.31≤f3/f≤0.93. The system has good imaging quality and lower sensitivity by reasonably distributing the focal power. Preferably, the camera optical lens 10 further satisfies a condition of 0.49≤f3/f≤0.74.

An on-axis thickness of the third lens L3 is defined as d5, and the total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis is defined as TTL. The camera optical lens 10 satisfies a condition of 0.11≤d5/TTL≤0.33. When the above condition is satisfied, it is beneficial for realization of ultra-thin lenses. Preferably, the camera optical lens 10 further satisfies a condition of 0.17≤d5/TTL≤0.26.

In this embodiment, an object side surface of the fourth lens L4 is convex in a paraxial region and an image side surface of the fourth lens L4 is concave in the paraxial region.

The focal length of the fourth lens L4 is defined as f4 and the focal length of the camera optical lens 10 is defined as f. The camera optical lens 10 satisfies a condition of −1.64≤f4/f≤−0.52, which specifies a ratio between the focal length f4 of the fourth lens L4 and the focal length f of the camera optical lens 10. When the above condition is satisfied, it is beneficial for improving optical system performance. Preferably, the camera optical lens 10 further satisfies a condition of −1.03≤f4/f≤−0.65.

A central curvature radius of the object side surface of the fourth lens L4 is defined as R7, and a central curvature radius of the image side surface of the fourth lens L4 is defined as R8. The camera optical lens 10 satisfies a condition of 1.12≤(R7+R8)/(R7−R8)≤3.81, which specifies a shape of the fourth lens L4. With the development towards ultra-thin and wide-angle lenses, it is beneficial for solving a problem like chromatic aberration of the off-axis picture angle, when the above condition is satisfied. Preferably, the camera optical lens 10 further satisfies a condition of 1.79≤(R7+R8)/(R7−R8)≤3.05.

A central on-axis thickness of the fourth lens L4 satisfies is defined as d7, and the total optical length from an object side surface of the first lens to an image surface of the camera optical lens along an optical axis is defined as TTL. The camera optical lens 10 satisfies a condition of 0.05≤d7/TTL≤0.15. When the above condition is satisfied, it is beneficial for the realization of ultra-thin lenses. Preferably, the camera optical lens 10 further satisfies a condition of 0.07≤d7/TTL≤0.12.

It shall be understood that in other embodiments, the object side surfaces and the image side surfaces of the first lens L1, the second lens L2, the third lens L3 and the fourth lens L4 may be provided as having convex or concave shapes other than those described above.

In this embodiment, a field of view FOV of the camera optical lens 10 is greater than or equal to 79°, thus realizing a wide angle.

In this embodiment, an aperture value FNO of the camera optical lens 10 is less than or equal to 1.95, thus realizing a large aperture, and thereby the camera optical lens 10 has good imaging performance.

In this embodiment, the total optical length of the camera optical lens is defined as TTL, and an image height of the camera optical lens 10 is defined as IH. The camera optical lens 10 satisfies a condition of TTL/IH≤1.76, which is beneficial for realization of ultra-thin lenses.

In this embodiment, the focal length of the camera optical lens 10 is defined as f, and a combined focal length of the first lens L1 and the second lens L2 is defined as f12. The camera optical lens 10 satisfies a condition of 0.91≤f12/f≤3.90. When the above condition is satisfied, the abbreviation and distortion of the camera optical lens can be removed, and the back focal length of the camera optical lens 10 can be suppressed, therefore maintaining the miniature of the imaging lens system. Preferably, the camera optical lens 10 further satisfies a condition of 1.46≤f12/f≤3.12.

When the above conditions are satisfied, the camera optical lens 10 has a large aperture, a wide angle, and an ultra-thinness while having good optical performance; and with such properties, the camera optical lens 10 is particularly suitable for a mobile camera lens assembly and a WEB camera lens that have CCD, CMOS and other imaging elements with high pixels.

In the following, an example will be taken to describe the camera optical lens 10 of the present disclosure. The symbols recorded in each example are as follows. The unit of the focal length, the on-axis distance, the curvature radius, the on-axis thickness, an inflexion point position and an arrest point position is mm.

TTL: Optical length (the total optical length from the object side surface of the first lens L1 to the image surface Si) in mm.

Aperture value FNO: Ratio of an effective focal length of the camera optical lens 10 to an entrance pupil diameter.

Preferably, inflexion points and/or arrest points may be arranged on the object side surface and/or image side surface of the lens, so as to satisfy the demand for high quality imaging. The description below may be referred to for specific implementations.

The design data of the camera optical lens 10 in Embodiment 1 of the present disclosure is shown in Tables 1 and 2.

TABLE 1

	R		d		nd		vd
S1	∞	d0 =	−0.029				
R1	2.053	d1 =	0.514	nd1	1.5439	v1	55.95
R2	−4.176	d2 =	0.184				
R3	7.391	d3 =	0.300	nd2	1.6400	v2	23.54
R4	1.986	d4 =	0.117				
R5	−3.077	d5 =	0.706	nd3	1.5439	v3	55.95
R6	−0.633	d6 =	0.068				
R7	1.261	d7 =	0.330	nd4	1.5439	v4	55.95
R8	0.482	d8 =	0.498				
R9	∞	d9 =	0.110	ndg	1.5168	vg	64.17
R10	∞	d10 =	0.389				

In the table, meanings of various symbols will be described as follows.

S1: Aperture;

R: curvature radius at a center of an optical surface;

R1: central curvature radius of the object side surface of the first lens L1;

R2: central curvature radius of the image side surface of the first lens L1;

R3: central curvature radius of the object side surface of the second lens L2;

R4: central curvature radius of the image side surface of the second lens L2;

R5: central curvature radius of the object side surface of the third lens L3;

R6:central curvature radius of the image side surface of the third lens L3;

R7: central curvature radius of the object side surface of the fourth lens L4;

vd: abbe number;

v1: abbe number of the first lens L1;

v2: abbe number of the second lens L2;

v3: abbe number of the third lens L3;

v4: abbe number of the fourth lens L4;

vg: abbe number of the optical filter GF.

Table 2 shows aspherical surface data of the camera optical lens **10** in Embodiment 1 of the present disclosure.

TABLE 2

	Conic coefficient	Aspherical surface coefficients				
	k	A4	A6	A8	A10	A12
R1	−1.0016E+01	−8.0004E−02	6.4675E−01	−7.0007E+00	1.8550E+01	2.6182E+00
R2	−1.1414E+02	−8.6695E−01	1.0154E+00	−2.0658E+00	6.8147E−01	1.9358E+01
R3	−1.2656E+02	−9.9775E−01	−9.3188E−01	6.4113E+00	−5.3413E+00	−7.1764E+00
R4	−1.6313E+00	−3.0085E−01	−9.7743E−01	3.1116E+00	−2.5479E+00	−3.1237E+00
R5	−9.5230E+01	2.9863E−01	−4.1882E−01	−9.4175E−01	2.3803E+00	1.1111E+00
R6	−9.4460E−01	6.9124E−01	−1.1579E+00	1.4653E+00	−5.4349E−01	−9.5266E−01
R7	−2.0387E+01	−2.3834E−01	−1.5159E−01	2.7595E−01	−1.4000E−01	−4.3988E−02
R8	−4.0955E+00	−3.0131E−01	2.6982E−01	−2.0297E−01	1.0474E−01	−3.6741E−02

	Conic coefficient	Aspherical surface coefficients			
	k	A14	A16	A18	A20
R1	−1.0016E+01	−1.1539E+02	1.5438E+02	0.0000E+00	0.0000E+00
R2	−1.1414E+02	−6.4615E+01	6.2536E+01	0.0000E+00	0.0000E+00
R3	−1.2656E+02	1.0673E+01	6.4737E−01	0.0000E+00	0.0000E+00
R4	−1.6313E+00	7.0796E+00	−3.6864E+00	0.0000E+00	0.0000E+00
R5	−9.5230E+01	−5.5414E+00	3.3689E+00	0.0000E+00	0.0000E+00
R6	−9.4460E−01	1.8589E+00	−8.8342E−01	0.0000E+00	0.0000E+00
R7	−2.0387E+01	4.8037E−02	−6.4209E−03	0.0000E+00	0.0000E+00
R8	−4.0955E+00	7.5980E−03	−7.1426E−04	0.0000E+00	0.0000E+00

R8: central curvature radius of the image side surface of the fourth lens L4;

R9:central curvature radius of an object side surface of the optical filter GF;

R10: central curvature radius of an image side surface of the optical filter GF;

d: on-axis thickness of a lens and an on-axis distance between lenses;

d0: on-axis distance from the aperture S1 to the object side surface of the first lens L1;

d1:on-axis thickness of the first lens L1;

d2: on-axis distance from the image side surface of the first lens L1 to the object side surface of the second lens L2;

d3: on-axis thickness of the second lens L2;

d4: on-axis distance from the image side surface of the second lens L2 to the object side surface of the third lens L3;

d5: on-axis thickness of the third lens L3;

d6: on-axis distance from the image side surface of the third lens L3 to the object side surface of the fourth lens L4;

d7: on-axis thickness of the fourth lens L4;

d8: on-axis distance from the image side surface of the fourth lens L4 to the object side surface of the optical filter GF;

d9: on-axis thickness of the optical filter GF;

d10: on-axis distance from the image side surface of the optical filter GF to the image surface Si;

nd: refractive index of d line;

nd1: refractive index of d line of the first lens L1;

nd2: refractive index of d line of the second lens L2;

nd3: refractive index of d line of the third lens L3;

nd4: refractive index of d line of the fourth lens L4;

ndg: refractive index of d line of the optical filter GF;

Among them, K is a conic index, A4, A6, A8, A10, A12, A14, A16, A18 and A20 are aspheric surface indexes.

$$y=(x^2/R)/\{1+[1-(k+1)(x^2/R^2)]^{1/2}\}+A4x^4+A6x^6+A8x^8+$$
$$A10x^{10}+A12x^{12}+A14x^{14}+A16x^{16}+A18x^{18}+$$
$$A20x^{20} \tag{1}$$

Where, x is a vertical distance from a point on an aspheric curve to the optical axis, and y is a depth of the aspheric surface (a vertical distance from a point on the aspheric surface having a distance x to the optical lens, to a tangent plane that tangents to a vertex on the optical axis of the aspheric surface).

For convenience, an aspheric surface of each lens surface uses the aspheric surfaces shown in the above formula (1). However, the present disclosure is not limited to the aspherical polynomials form shown in the formula (1).

Table 3 and table 4 show the inflexion points and the arrest point design data of the camera optical lens **10** lens in Embodiment 1 of the present disclosure. Where, P1R1 and P1R2 represent respectively the object side surface and image side surface of the first lens L1, P2R1 and P2R2 represent respectively the object side surface and image side surface of the second lens L2, P3R1 and P3R2 represent respectively the object side surface and image side surface of the third lens L3, and P4R1 and P4R2 represent respectively the object side surface and image side surface of the fourth lens L4. Data in the column named "inflexion point position" refers to vertical distances from the inflexion points arranged on each lens surface to the optic axis of the camera optical lens **10**. The data in the column named "arrest point position" refers to the vertical distances from the arrest points arranged on each lens surface to the optic axis of the camera optical lens **10**.

TABLE 3

	Number of inflexion points	Inflexion point position 1	Inflexion point position 2
P1R1	1	0.385	/
P1R2	0	/	/
P2R1	2	0.105	0.635
P2R2	1	0.315	/
P3R1	1	0.245	/
P3R2	1	0.665	/
P4R1	1	0.295	/
P4R2	1	0.395	/

TABLE 4

	Number of arrest points	Arrest point position 1
P1R1	0	/
P1R2	0	/
P2R1	1	0.175
P2R2	1	0.575
P3R1	1	0.695
P3R2	1	0.895
P4R1	1	0.575
P4R2	1	1.035

FIG. 2 and FIG. 3 illustrate a longitudinal aberration and a lateral color of light with wavelengths of 470 nm, 510 nm, 555 nm, 610 nm and 650 nm after passing the camera optical lens 10 according to Embodiment 1. FIG. 4 illustrates the field curvature and distortion of light with a wavelength of 555 nm after passing the camera optical lens 10 according to Embodiment 1, the field curvature S in FIG. 4 is a field curvature in the sagittal direction, T is a field curvature in a meridian direction.

The following Table 13 shows various values of Embodiments 1, 2, 3 and values corresponding to parameters which are already specified in the above conditions.

As shown in Table 13, Embodiment 1 satisfies the various conditions.

In this embodiment, the entrance pupil diameter ENPD of the camera optical lens 10 is 1.112 mm, a full vision field image height IH is 1.830 mm, a field of view FOV in a diagonal direction is 79.80°, thus the camera optical lens 10 has a large aperture, a wide-angle and is ultra-thin. Its on-axis and off-axis chromatic aberrations are fully corrected, thereby achieving excellent optical characteristics.

Embodiment 2

FIG. 5 illustrates a camera optical lens 20 according to Embodiment 2 of the present disclosure. Embodiment 2 is basically the same as Embodiment 1 and involves symbols having the same meanings as Embodiment 1, and only differences therebetween will be described in the following. Table 5 and table 6 show design data of a camera optical lens 20 in Embodiment 2 of the present disclosure.

TABLE 5

	R	d		nd		vd	
S1	∞	d0 =	−0.050				
R1	1.823	d1 =	0.599	nd1	1.5439	v1	55.95
R2	−4.153	d2 =	0.156				
R3	10.930	d3 =	0.239	nd2	1.6400	v2	23.54
R4	2.290	d4 =	0.140				
R5	−2.203	d5 =	0.693	nd3	1.5439	v3	55.95
R6	−0.612	d6 =	0.060				
R7	1.164	d7 =	0.307	nd4	1.5439	v4	55.95
R8	0.465	d8 =	0.498				
R9	∞	d9 =	0.110	ndg	1.5168	vg	64.17
R10	∞	d10 =	0.397				

Table 6 shows aspherical surface data of each lens of the camera optical lens 20 in Embodiment 2 of the present disclosure.

TABLE 6

	Conic Coefficient	Aspheric Surface Indexes				
	k	A4	A6	A8	A10	A12
R1	−7.2767E+00	−4.5260E−03	1.2827E+00	−2.2685E+01	1.7094E+02	−7.0539E+02
R2	−4.1403E+01	−7.1627E−01	7.7605E−01	−1.9034E+00	2.3564E+00	7.6768E+00
R3	−1.5423E+01	−1.1515E+00	9.4086E−01	−6.7236E+00	4.9358E+01	−1.4136E+02
R4	2.0033E+00	−3.8770E−01	−5.5149E−01	2.6495E+00	−4.7110E+00	3.8172E+00
R5	−1.1145E+01	4.9589E−01	−1.3210E+00	2.8695E+00	−8.6831E+00	1.7749E+01
R6	−9.2785E−01	8.5814E−01	−1.2396E+00	−5.6970E−01	8.2411E+00	−1.7797E+01
R7	−2.1000E+01	−7.4498E−03	−7.8533E−01	1.5037E+00	−1.6123E+00	9.9034E−01
R8	−4.1508E+00	−2.6752E−01	2.2785E−01	−1.8656E−01	1.1247E−01	−4.7348E−02

	Conic Coefficient	Aspheric Surface Indexes			
	k	A14	A16	A18	A20
R1	−7.2767E+00	1.4929E+03	−1.2793E+03	0.0000E+00	0.0000E+00
R2	−4.1403E+01	−3.4036E+01	3.3886E+01	0.0000E+00	0.0000E+00
R3	−1.5423E+01	1.8224E+02	−8.6629E+01	0.0000E+00	0.0000E+00
R4	2.0033E+00	−7.9464E−01	−2.2583E−01	0.0000E+00	0.0000E+00
R5	−1.1145E+01	−1.6471E+01	5.4578E+00	0.0000E+00	0.0000E+00
R6	−9.2785E−01	1.7467E+01	−6.4667E+00	0.0000E+00	0.0000E+00
R7	−2.1000E+01	−3.0692E−01	3.5803E−02	0.0000E+00	0.0000E+00
R8	−4.1508E+00	1.1893E−02	−1.3195E−03	0.0000E+00	0.0000E+00

Table 7 and table 8 show design data of inflexion points and arrest points of respective lens in the camera optical lens **20** according to Embodiment 2 of the present disclosure.

TABLE 7

	Number of inflexion points	Inflexion point position 1	Inflexion point position 2
P1R1	1	0.445	/
P1R2	0	/	/
P2R1	2	0.085	0.655
P2R2	2	0.305	0.775
P3R1	1	0.635	/
P3R2	1	0.675	/
P4R1	2	0.335	1.115
P4R2	1	0.395	/

TABLE 8

	Number of arrest points	Arrest point position 1
P1R1	0	/
P1R2	0	/
P2R1	1	0.145
P2R2	1	0.555
P3R1	1	0.785
P3R2	1	0.885
P4R1	1	0.645
P4R2	1	1.045

FIG. **6** and FIG. **7** illustrate a longitudinal aberration and a lateral color of light with wavelengths of 470 nm, 510 nm, 555 nm, 610 nm and 650 nm after passing the camera optical lens **20** according to Embodiment 2. FIG. **8** illustrates a field curvature and a distortion of light with a wavelength of 555 nm after passing the camera optical lens **20** according to Embodiment 2. The field curvature S in FIG. **8** is a field curvature in a sagittal direction, and T represents field curvature in meridian direction.

As shown in Table 13, Embodiment 2 satisfies the above conditions.

In this embodiment, the entrance pupil diameter ENPD of the camera optical lens **20** is 1.113 mm. The full vision field image height IH is 1.830 mm, the field of view FOV in the diagonal direction is 79.40°. Thus, the camera optical lens **20** has a large aperture, a wide-angle and is ultra-thin. Its on-axis and off-axis chromatic aberrations are fully corrected, thereby achieving excellent optical characteristics.

Embodiment 3

FIG. **9** illustrates a camera optical lens **30** according to Embodiment 3 of the present disclosure. Embodiment 3 is basically the same as Embodiment 1 and involves symbols having the same meanings as Embodiment 1, and only differences therebetween will be described in the following.

Table 9 and Table 10 show design data of a camera optical lens **30** in Embodiment 3 of the present disclosure.

TABLE 9

	R	d		nd		vd	
S1	∞	d0 =	−0.009				
R1	2.366	d1 =	0.512	nd1	1.5439	v1	55.95
R2	−3.700	d2 =	0.172				
R3	5.259	d3 =	0.306	nd2	1.6400	v2	23.54
R4	1.694	d4 =	0.166				
R5	−6.599	d5 =	0.681	nd3	1.5439	v3	55.95
R6	−0.681	d6 =	0.060				
R7	1.026	d7 =	0.300	nd4	1.5439	v4	55.95
R8	0.446	d8 =	0.498				
R9	∞	d9 =	0.110	ndg	1.5168	vg	64.17
R10	∞	d10 =	0.409				

Table 10 shows aspherical surface data of each lens of the camera optical lens **30** in Embodiment 3 of the present disclosure.

TABLE 10

	Conic Coefficient	Aspheric Surface Indexes				
	k	A4	A6	A8	A10	A12
R1	3.3235E+00	−1.1808E−01	−2.4193E+00	2.8171E+01	−2.0509E+02	8.1270E+02
R2	−2.0072E+01	−7.8722E−01	1.0437E+00	−1.9622E+00	2.4976E−01	1.3073E+01
R3	−2.0564E+01	−1.1642E+00	1.4959E+00	−4.7477E+00	2.8270E+01	−7.5449E+01
R4	1.3547E−01	−6.1466E−01	4.4555E−01	−5.2467E−01	1.9246E+00	−4.3344E+00
R5	−7.3953E+00	4.3163E+00	−9.0830E−01	1.1440E+00	−1.9103E+00	2.8074E+00
R6	−9.0115E−01	5.9155E−01	3.1361E−01	−4.9515E+00	1.5225E+01	−2.3365E+01
R7	−1.7888E+01	−1.7050E−01	−1.6758E−01	−9.5144E−02	8.2376E−01	−1.2452E+00
R8	−3.8547E+00	−3.0207E−01	3.0165E−01	−2.9273E−01	2.0774E−01	−9.7578E−02

	Conic Coefficient	Aspheric Surface Indexes			
	k	A14	A16	A18	A20
R1	3.3235E+00	−1.6728E+03	1.3898E+03	0.0000E+00	0.0000E+00
R2	−2.0072E+01	−3.6687E+01	3.1718E+01	0.0000E+00	0.0000E+00
R3	−2.0564E+01	9.4041E+01	−4.5229E+01	0.0000E+00	0.0000E+00
R4	1.3547E−01	4.8001E+00	−2.0761E+00	0.0000E+00	0.0000E+00
R5	−7.3953E+00	−1.5404E+00	6.4618E−02	0.0000E+00	0.0000E+00
R6	−9.0115E−01	1.8395E+01	−5.7556E+00	0.0000E+00	0.0000E+00
R7	−1.7888E+01	8.2896E−01	−2.0584E−01	0.0000E+00	0.0000E+00
R8	−3.8547E+00	2.6351E−02	−3.0730E−03	0.0000E+00	0.0000E+00

Table 11 and table 12 show design data of inflexion points and arrest points of respective lens in the camera optical lens **30** according to Embodiment 3 of the present disclosure.

TABLE 11

	Number of inflexion points	Inflexion point position 1	Inflexion point position 2	Inflexion point position 3
P1R1	1	0.365	/	/
P1R2	0	/	/	/
P2R1	2	0.125	0.625	/
P2R2	1	0.325	/	/
P3R1	3	0.195	0.555	0.665
P3R2	1	0.665	/	/
P4R1	1	0.315	/	/
P4R2	1	0.395	/	/

TABLE 12

	Number of arrest points	Arrest point position 1
P1R1	1	0.545
P1R2	0	/
P2R1	1	0.205
P2R2	1	0.635
P3R1	1	0.365
P3R2	1	0.915
P4R1	1	0.615
P4R2	1	1.055

FIG. **10** and FIG. **11** illustrate a longitudinal aberration and a lateral color of light with wavelengths of 470 nm, 510 nm, 555 nm, 610 nm and 650 nm after passing the camera optical lens **30** according to Embodiment 3. FIG. **12** illustrates field curvature and distortion of light with a wavelength of 555 nm after passing the camera optical lens **30** according to Embodiment 3. The field curvature S in FIG. **12** is a field curvature in a sagittal direction, and T represents field curvature in meridian direction.

The following Table 13 shows the values corresponding to the conditions in this embodiment according to the above conditions. Obviously, the camera optical lens **30** according to this embodiment satisfies the various conditions.

In this embodiment, a pupil entering diameter ENPD of the camera optical lens is 1.108 mm, a full vision field image height is 1.830 mm, and a vision field angle in the diagonal direction is 80.00°. Thus, the camera optical lens **30** is a wide-angle and is ultra-thin. Its on-axis and off-axis chromatic aberrations are fully corrected, thereby achieving excellent optical characteristics.

TABLE 13

Parameters and conditions	Embodiment 1	Embodiment 2	Embodiment 3
(R1 + R2)/ (R1 – R2)	−0.34	−0.39	−0.22
(R3 + R4)/ (R3 – R4)	1.74	1.53	1.95
(R5 + R6)/ (R5 – R6)	1.52	1.77	1.23
d3/d2	1.63	1.53	1.78
f	2.168	2.170	2.160
f1	2.598	2.407	2.726
f2	−4.305	−4.541	−4.009
f3	1.325	1.347	1.336
f4	−1.684	−1.682	−1.772
f12	4.709	3.966	5.612
FNO	1.950	1.950	1.949

TABLE 13-continued

Parameters and conditions	Embodiment 1	Embodiment 2	Embodiment 3
TTL	3.216	3.199	3.214
IH	1.830	1.830	1.830
FOV	79.80	79.40	80.00

It can be appreciated by one having ordinary skill in the art that the description above is only embodiments of the present disclosure. In practice, one having ordinary skill in the art can make various modifications to these embodiments in forms and details without departing from the spirit and scope of the present disclosure.

What is claimed is:

1. A camera optical lens, comprising four lenses in total, the four lenses are, from an object side to an image side in sequence:

a first lens having a positive refractive power;

a second lens having a negative refractive power;

a third lens having a positive refractive power; and

a fourth lens having a negative refractive power;

wherein, the camera optical lens satisfies the following conditions:

$$-0.40 \leq (R1+R2)/(R1-R2) \leq -0.20;$$

$$1.50 \leq (R3+R4)/(R3-R4) \leq 2.00;$$

$$1.20 \leq (R5+R6)/(R5-R6) \leq 1.80; \text{ and}$$

$$1.52 \leq d3/d2 \leq 1.80;$$

where,

R1 denotes a central curvature radius of an object side surface of the first lens;

R2 denotes a central curvature radius of an image side surface of the first lens;

R3 denotes a central curvature radius of an object side surface of the second lens;

R4 denotes a central curvature radius of an image side surface of the second lens;

R5 denotes a central curvature radius of an object side surface of the third lens;

R6 denotes a central curvature radius of an image side surface of the third lens; and

d2 denotes an on-axis distance from the image side surface of the first lens to the object side surface of the second lens L2; and

d3 denotes an on-axis thickness of the second lens.

2. The camera optical lens according to claim **1**, wherein, the camera optical lens further satisfies the following conditions:

$$-0.70 \leq f1/f2 \leq -0.50;$$

where,

f1 denotes a focus length of the first lens; and

f2 denotes a focus length of the second lens.

3. The camera optical lens according to claim **1**, wherein, the camera optical lens further satisfies the following conditions:

$$0.55 \leq f1/f \leq 1.89; \text{ and}$$

$$0.08 \leq d1/TTL \leq 0.28;$$

where,

f denotes a focus length of the camera optical lens;

f1 denotes a focus length of the first lens;

d1 denotes an on-axis thickness of the first lens; and

TTL denotes a total optical length from the object side surface of the first lens to an image surface of the camera optical lens along an optical axis.

4. The camera optical lens according to claim **1**, wherein, the camera optical lens further satisfies the following conditions:

$$-4.19 \leq f2/f \leq -1.24; \text{ and}$$

$$0.04 \leq d3/TTL \leq 0.14;$$

where,

f denotes a focus length of the camera optical lens;

f2 denotes a focus length of the second lens; and

TTL denotes a total optical length from the object side surface of the first lens to an image surface of the camera optical lens along an optical axis.

5. The camera optical lens according to claim **1**, wherein, the camera optical lens further satisfies the following conditions:

$$0.31 \leq f3/f \leq 0.93; \text{ and}$$

$$0.11 \leq d5/TTL \leq 0.33;$$

where,

f denotes a focus length of the camera optical lens;

f3 denotes a focus length of the third lens;

d5 denotes an on-axis thickness of the third lens; and

TTL denotes a total optical length from the object side surface of the first lens to an image surface of the camera optical lens along an optical axis.

6. The camera optical lens according to claim **1**, wherein, the camera optical lens further satisfies the following conditions:

$$-1.64 \leq f4/f \leq -0.52;$$

$$1.12 \leq (R7+R8)/(R7-R8) \leq 3.81; \text{ and}$$

$$0.05 \leq d7/TTL \leq 0.15;$$

where,

f denotes a focus length of the camera optical lens;

f4 denotes a focus length of the fourth lens;

R7 denotes a central curvature radius of an object side surface of the fourth lens;

R8 denotes a central curvature radius of an image side surface of the fourth lens;

d7 denotes an on-axis thickness of the fourth lens; and

TTL denotes a total optical length from the object side surface of the first lens to an image surface of the camera optical lens along an optical axis.

7. The camera optical lens according to claim **1**, wherein the camera optical lens further satisfies the following conditions:

$$FNO \leq 1.95;$$

where,

FNO denotes an aperture value of the camera optical lens.

8. The camera optical lens according to claim **1**, wherein the camera optical lens further satisfies the following conditions:

$$FOV \geq 79°;$$

where,

FOV denotes a field of view of the camera optical lens.

9. The camera optical lens according to claim **1**, wherein, the camera optical lens further satisfies the following conditions:

$$TTL/IH \leq 1.76;$$

where,

TTL denotes a total optical length from the object side surface of the first lens to an image surface of the camera optical lens along an optical axis; and

IH denotes an image height of the camera optical lens.

10. The camera optical lens according to claim **1**, wherein the camera optical lens further satisfies the following conditions:

$$0.91 \leq f12/f \leq 3.90;$$

where,

f denotes a focus length of the camera optical lens; and

f12 denotes a combined focal length of the first lens and the second lens.

* * * * *